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Life Cycle of *Steatoda paykulliana* (Walckenaer, 1805) in Egypt (Araneida : Theridiidae)

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Abstract

Steatoda paykulliana (Walckenaer, 1805), family Theridiidae, was found among wild plants in Sallant village, near El-Mansoura city, El-Dakahlia Governorate, Egypt. Its life cycle was studied in laboratory. Males reached maturity after 6-7 spiderling instars (200 ± 12.6 days), and females after 6-8 spiderling instars (223 ± 24.7 days). Different instars were reared on different stages of larvae of cotton leaf worm. Food consumption was studied, in addition to an experiment of food preference. Mating behaviour was briefly described.

Keywords: Life cycle, Feeding, Food preference, Mating behaviour, Spiders, Theridiidae, *Steatoda paykulliana*, Egypt.

Introduction

Family Theridiidae is one of the most important families of spiders. It includes 2208 species of 80 genera distributed all over the world (Platnick, 2003). Six species of genus *Steatoda* Sundevall, 1833 are recorded among 25 species of 10 genera of Theridiidae in Egypt (El-Hennawy, 2002a, 2002b).

Steatoda paykulliana (Walckenaer, 1805) was recorded from Alexandria and southern Sinai (El-Hennawy, 2002a). There are no studies on *S. paykulliana* in Egypt till now, while there is only an unpublished study of *Steatoda triangulosa* (Walckenaer, 1802) by Rahil (1988). Therefore, it is necessary to study its life cycle and to try to know its role in the agroecosystem.

Material and Methods

Adult female of *Steatoda paykulliana* (Walckenaer, 1805) was collected on 28th March 2003 from Sallant village near El-Mansoura city, El-Dakahlia Governorate, Egypt. It was found among wild plants adjacent to cultivated plants. It was reared inside a test tube where she laid an egg sac on 19th April 2003 which was observed till hatching. The hatched spiderlings were individually reared inside translucent plastic containers (3 cm in diameter and 5 cm in length); the upper lid of the container was perforated for ventilation. All obtained spiderlings were reared under laboratory conditions of 26-28°C and 60-70 % R.H. They were fed once every two days on different stages of 1st-4th instars of larvae of cotton leaf worm, *Spodoptera littoralis* (Boisduval, 1833).

After reaching adulthood, 10 couples of a male and a female were reared in separate containers to observe mating behaviour and oviposition.

An experiment of food preference by 16 adult females was achieved on three insect species, i.e. larvae of *Spodoptera littoralis* (Order Lepidoptera, Family Noctuidae), and adults of the Mediterranean fruit-fly *Ceratitis capitata* (Wiedemann, 1824) and the Peach fruit-fly *Bactrocera zonata* (Saunders, 1841) (Order Diptera, Family Tephritidae).

Results and Discussion

Egg sac, eggs and incubation period

The egg sac was spherical in shape, white in colour at first and became dark before hatching. The eggs inside the egg sac were circular and yellow at the beginning, after laying, and became dark before hatching. On 14th May 2003, 58 individuals hatched and emerged from the egg sac through a round pore at the tip of the egg sac, they were reared under laboratory conditions. The incubation period of eggs of *S. paykulliana* lasted for 25 days.

Spiderlings

During rearing the 58 spiderlings of *S. paykulliana*, 4 individuals escaped before reaching maturity, 14 individuals died before adulthood, 40 individuals reached adult stage.

The spiderlings passed through 6-7 instars for males and 6-8 instars for females during their development (Table 1). Twenty percent of males became adult after six moults, while the eighty percent moulted seven times. Most females (52.27%) reached maturity after seven moults, while 8.60% only moulted six times and 39.13% moulted eight times. The longest duration was that of the 5th instar of female and the 6th instar of male. The shortest instar was the 1st through the 3rd ones for both male and female.

In this respect, Rahil (1988) observed that the female of *Steatoda triangulosa* (Walckenaer, 1802) passed through 3-4 instars and the male passed through 2-4 instars at 25°C when they fed on *Musca domestica* (Linnaeus, 1758). Hussein *et al.* (2003) studied some biological aspects of *Anelosimus aulicus* (Koch, 1838) (Theridiidae), feeding on *Tetranychus urticae* Koch, 1836, *Aphis craccivora* Koch, 1854 and a mixture of both of them. *A. aulicus* passed through five spiderling instars before reaching adulthood for both male and female.

Sex ratio

The sex ratio of adults was 1 : 1.35 (male : female) and this differed that of *S. triangulosa* which was 1 : 1.1 (Rahil, 1988).

Table 1: Duration of the different developmental stages of the theridiid spider *Steatoda paykulliana* (Walckenaer, 1805) in Egypt.

Developmental Stage	Duration (Days)					
	Male			Female		
	Range	Mean	S.D	Range	Mean	S.D
1 st Instar	7-14	10	1.5	7-16	11	2.1
2 nd Instar	5-24	13	6.1	5-26	13	6
3 rd Instar	7-22	15	4.5	9-34	16	5.8
4 th Instar	17-73	25	14	8-75	27	18
5 th Instar	25-70	45	13	37-78	54	11
6 th Instar	23-77	53	12	26-60	44	8.9
7 th Instar	34-65	48	8.7	22-77	45	18
8 th Instar	--	--	--	28-56	45	8.6
Life cycle	189-236	200	12.6	171-294	223	24.7

Food consumption

During the study of food consumption of *S. paykulliana*, different spiderling instars and adults were fed on various instars of *S. littoralis* larvae. Both first and second instars of spiderlings were fed on the first instar of *S. littoralis*. Third and fourth instars of spiderlings were fed on the second instar of prey. Fifth and sixth instars of spiderlings were fed on the third instar of the prey, while the seventh and eighth instars of spiderlings were fed on the fourth instar of the prey. Number of consumed preys by different spiderling instars is in Table 2.

Table 2: Food consumption of the theridiid spider *Steatoda paykulliana* (Walckenaer, 1805) in Egypt, feeding on larvae of *Spodoptera littoralis* (Boisduval, 1833).

Developmental Stage	Number of consumed individuals of prey					
	Male			Female		
	Range	Mean	S.D.	Range	Mean	S.D.
1 st Instar	15-30	21	3.38	3.39-29	21.7	6.24
2 nd Instar	5-30.5	13.1	7.04	5-32.5	15.3	8.9
3 rd Instar	15-35	23.8	5.37	9.05-60.5	28	10.9
4 th Instar	31.5-80	45.9	12.1	20-110	44.9	28.2
5 th Instar	67.5-120	97.3	13.4	20-170	108	46.7
6 th Instar	57.5-135	97.9	19.3	21.6-128	86.7	30.1
7 th Instar	70-110	89	12.8	22.6-125	69.2	23.9
8 th Instar	--	--	--	15-92.5	48.3	26.5
Life cycle	311-410	370.2	25.4	322-498	384.8	89.4

Food preference

This experiment depended on 16 adult females. It was performed to investigate the feeding preference of the adult female of *S. paykulliana*, using three different preys. The preys were *S. littoralis*, *C. capitata* and *B. zonata*. The results revealed that:

- 6.25 % of the female spiders immediately attacked larvae and only fed on them.
- 56.25 % of the spiders immediately attacked flies and only fed on them
- 12.50 % of the spiders paralyzed larvae at first without feeding, then attacked flies and fed on them.
- 25% of the spiders did not feed on any of the available preys.

Mating behaviour

The mating behaviour of 10 couples of a male and a female *S. paykulliana* was observed. Mating process was achieved through the following steps:

1. The approach of both the male and the female towards each other until touching of their legs.
2. Rubbing male's pedipalps by each other.
3. More approach between male and female and overlapping of their legs.
4. Pedipalp of the male comes in contact with the cephalothorax of the female trying to reach the epigynum (about 5 times).
5. Male inserts the tip of the left palpal organ inside the epigynum of the female with contracting and relaxing of the male's abdomen (10 minutes).
6. Male leaves the female with rubbing the pedipalps with each other.
7. Female comes near the male which repeats the steps 3-5 but with the right palpal organ (8 minutes).

Notes on mating and devouring

1. 30% of the females mated with males and did not devour them.
2. 30% of the females did not mate with nor devour males.
3. 40% of the females did not mate with males and devoured them one day later.
4. In one case, a male mated two times with two separate different females.

It is obvious that devouring male in this species is not related to mating with female. They may live in the same area for a few days without cannibalism.

Acknowledgment

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Intraspecific diversity of morphological characters of the burrowing scorpion *Scorpio maurus palmatus* (Ehrenberg, 1828) in Egypt (Arachnida: Scorpionida: Scorpionidae)

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Abstract

The general objective of the present study is to examine the intraspecific variations in the morphological characters of the scorpion, *Scorpio maurus palmatus*, populations inhabiting different geographic regions in Egypt. Whereas the specific objective is dealing with the impact of the environmental factors, biotic and abiotic, on the intraspecific variations of this scorpion species. Scorpions were collected from three locations in South Sinai, i.e. Wadi Sahab, Wadi El-Agramia, Wadi Rahaba, which represent the arid area and a region in the Western Mediterranean Coastal Desert (WMCD), which represents the semiarid area. Random soil samples were taken from all sites for physical and chemical analysis as well as the available plants and insects around the scorpions burrows were collected and identified. The depths of the scorpions' burrows were measured and their different shapes were recorded. Several statistical analyses were carried out for the tested parameters to explain the complicated interaction between them. Most of the morphometric measurements (total body length, pedipalp length, pedipalp hand width, number of setae on legs and number of pectinal teeth) revealed highly significant differences within and among populations. Pearson correlation matrix of some morphometric measurements and environmental factors (altitude, soil nature, climate) showed an interaction between them. Discriminant Functions Analysis (DFA) and Hierarchical Cluster Analysis (HCA) showed that WMCD population is highly distinct from the other populations in Sinai. These results indicated that: 1- *Scorpio maurus palmatus* exhibits a general morphological separation between populations, 2- intraspecific diversity in this species may be due to variation in the environmental conditions (biotic and abiotic factors), and 3- total body length, pedipalp length as well as number of setae can be used as good markers to examine intraspecific diversity of most scorpion species.

Keywords: Intraspecific diversity, South Sinai, Western Mediterranean Coastal Desert, Egypt, Scorpions, Scorpionidae, *Scorpio maurus palmatus*.

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Introduction

Scorpions, members of class Arachnida, are very ancient chelicerate arthropods. Order Scorpionida (Scorpiones) includes 1259 described species in 16 living families and 155 genera (Fet *et al.*, 2000). Scorpions live in tropical and temperate regions of the world, within 50 degrees North and South of the Equator. They live in forests, savannas, deserts, and some species are even found in mountains over 5000m of altitude. All scorpions are nocturnal, hiding during the day under stones, wood, or tree bark, in termite hills, and other protected places. Some species seem to be attracted by human habitation and live around the human dwellings and even inside of them (Anderson, 1983).

Although, scorpions are one of the oldest and most common animals in the world, they had received little attention from the biological point of view. In Egypt, most of publications dealt with the toxicity of its venom (Omran *et al.*, 1992a and b; Omran & Abdel-Rahman 1992 and 1994; Omran & McVean, 2000; Omran, 2003). A few publications dealt with its morphology, anatomy, embryology and histology (Khalil *et al.*, 1983a, b and 1985; El-Bakary, 1990 and 1998); systematics and ecology (El-Hennawy, 1987, 1992 and 2002; Moustafa, 1988); and physiology (El-Bakary, 1986).

Scorpions were known to people since ancient eras. The ancient Egyptians documented them in their writings. Modern scientific writings did not mention scorpions until 1825 in the book “*Description de l'Égypte*” and what was recorded by the French scientist Savigny and completed by his student Audouin and contained a description of three species of one family. A few publications followed during the nineteenth and twentieth centuries introducing us to more species of scorpions that live in Egypt. The list of Egyptian scorpions currently includes 24 species classified under 13 genera of four different families, Buthidae, Diplocentridae, Euscorpiidae and Scorpionidae, (El-Hennawy, 2002).

Genus *Scorpio* belongs to subfamily Scorpioninae, Family Scorpionidae. It is recorded from North Africa, Middle East to Iran and Arabia. It is now generally accepted that there is only one species in this genus: *Scorpio maurus* (Linnaeus, 1758) which includes 18 subspecies (Fet *et al.*, 2000). *Socrpio maurus palmatus* (Ehrenberg 1828) is mainly recorded in Egypt from near Alexandria, Wadi Natrun, Cairo, El-Faiyum and Sinai (El-Hennawy, 1992, 2002). A good full description of *S. m. palmatus* is included in the work of Levy and Amitai (1980). It was chosen to study the intraspecific diversity of scorpions' morphology in Egypt in this study. It is found on browned sandy soils, loess and alluvial soils and in stony desert. It burrows and can move stones heavier than itself. Each scorpion lives alone in a burrow, but concentrations of hundreds of burrows may be found in certain areas. The burrows have a crescent-shaped opening and run fairly parallel to the ground for about 10 cm after which it runs downwards for 20 to 70 cm. The bottom is slightly enlarged. The animal leaves the burrow at night or stands at the entrance with the pincers slightly raised. Parturition occurs in August-September with 8-13 young scorpions. *S. m. palmatus* preys small and large arthropods. It does not sting readily and the sting is not very painful to humans (Levy & Amitai, 1980). Males have been observed (Rosin & Shulov, 1961) to produce sounds by rapidly striking the posterior half of the mesosoma against the ground. This species prefers areas of high precipitation, dense vegetation and deep soil. Apparently, these factors also provide them with a suitable microclimate for maintaining optimal water and thermal balance (Warburg *et al.*, 1980).

The general objective of the present study is to examine the intraspecific variations in the morphological characters of the scorpion, *Scorpio maurus palmatus*, populations inhabiting different geographic regions in Egypt. Whereas the specific

objective is dealing with the impact of the environmental factors, biotic and abiotic, on the intraspecific variations of this scorpion species.

The study area

The present study was carried out in two different geographical regions in Egypt (Fig. 1). The first was located in the southern part of Sinai Peninsula, which represents the arid area and is geographically separated from the rest of the Egyptian land by the Suez Canal and the Gulf of Suez. Three locations in this region were chosen as separate wadis (valleys) near Saint Catherine (Wadi Sahab 28°42'33"N 33°47'16"E 910m Altitude, Wadi El-Agramia 28°45'39"N 33°54'39"E 1225m Alt., and Wadi Rahaba 28°25'154"N 33°59'54"E 1676m Alt.). The second region was located in the Western Mediterranean Coastal Desert (WMCD), west of Alexandria, which represents the semi arid area (30°55'91"N 29°35'27"E 30.5m Alt.).

A. Sinai Peninsula

1. Locations and Geography

Sinai Peninsula (Fig. 1) is a triangular plateau (61000 km²) occupying the north-eastern corner of Egypt (Said, 1990). South Sinai area is about 28400 km², 46% of the total area of Sinai Peninsula (South Sinai Governorate, 1997). The study area (Fig. 2) was located between latitudes 28°10' and 29°10' N, and longitudes 33°15' and 34°39' E. It covers three main areas representing different vegetation types, altitudinal variation, landform and climatic variations. These areas are: 1- Wadi El-Agramia in the centre of South Sinai, 2- Wadi Sahab in the west, and 3- Wadi Rahaba in the east (Fig. 2).

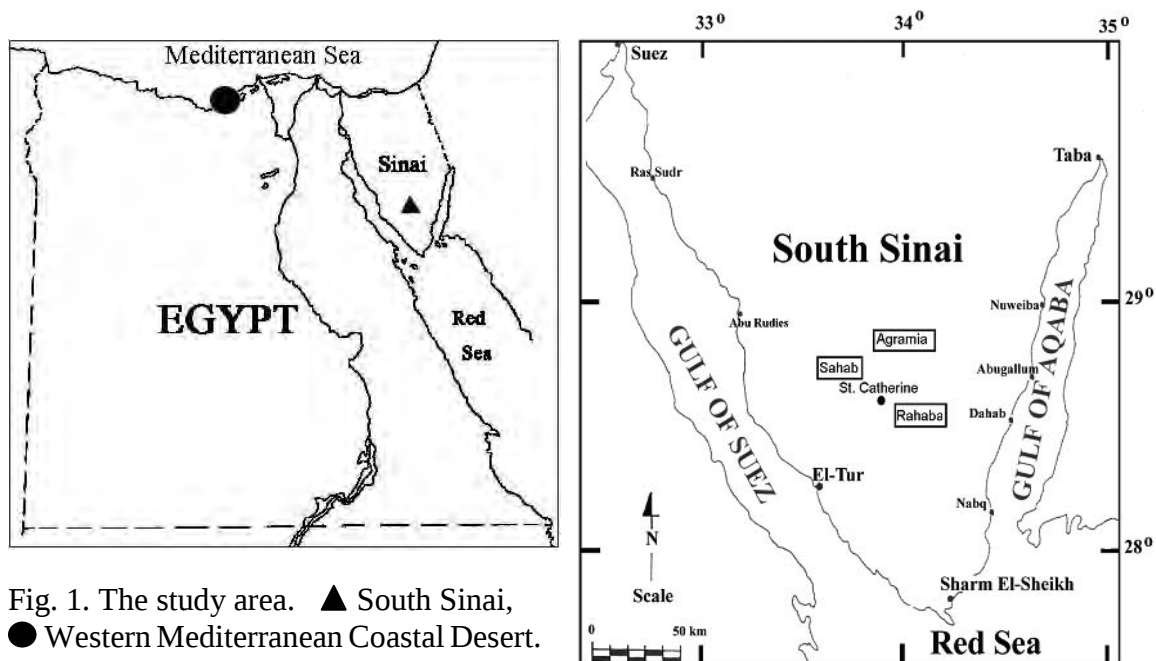


Fig. 1. The study area. ▲ South Sinai, ● Western Mediterranean Coastal Desert.

Fig. 2. Location map of South Sinai showing the study areas (Wadi Sahab, Wadi El-Agramia and Wadi Rahaba) around St. Catherine.

2. Geology and Geomorphology

The northern part of Sinai is almost entirely covered by sedimentary rocks, mostly limestone. In the southern part, the basement rocks occupy about 7000 km² surface area,

forming a triangular mass of mountains with its apex at Ras Mohammad to the south. The Sinai massif contains much granite and other magmatic and metamorphic rocks (Hammad, 1980). The Sinai massive is dissected by numerous incised wadis. The highest peak, Gebel (Mountain) Catherine attains an altitude of 2641m above sea level. Due to the Massif Mountains in the centre, South Sinai has a wide range of altitudinal variation (Said, 1990). The altitudinal gradient decreases from St. Catherine area going eastward till Gulf of Aqaba and westward till Gulf of Suez.

The study area has two main landform types: Wadis and Plains. The term wadi designates a dried riverbed in a desert area. A wadi may be transformed into a temporary watercourse after heavy rain. Wadi bed is covered with alluvial deposits with different thickness and structure from location to another. The soil is usually composed of the same composition as the parent rocks and varied in texture from fine silt or clay to gravels and boulders (Kassas, 1952 and Kassem, 1981). In general, the depth of alluvial deposits and smoothness has a negative relation with the altitude. Plains are flat expanses of desert where deep alluvial deposits are found. The desert plains represent a very late stage in the arid erosion cycle (Kassas, 1952).

2.1. Wadi El-Agramia (Fig. 2) is one of the most important physiographic features of St. Catherine area. It is located about 30 km to the northeast of St. Catherine city and covers an area of about 25 km². It is a gravel-stream wide plain with surface cobbles and about 10% of the basal area. The area has two main localities; Agramia plain, and Wadi Hargos. The altitude of the area ranges between 1000 to 1500m above sea level. Geographically, the exposed rocks in the area are granitoids with some basic to intermediate dykes. Separate granitic outcrops are sporadically distributed over the general slope of the study area and towards the entrance of Wadi Hargos (Shendi, 1992).

2.2. Wadi Rahaba (Fig. 2) lies in the south of St. Catherine as a part of Wadi Nasb Basin. It is filled with alluvial deposits of gravelled and coarse sandy soil surface. The plain is surrounded by granitic hills. Nasb Basin starts from south of St. Catherine and runs eastward to Dahab city on the Gulf of Aqaba. This basin includes Wadi El-Asbaiya, Wadi Rasis, Wadi Talat El-Ghofra, Wadi Rahaba, Wadi Nasb and Wadi Zahara. The nature of soil surface starts rocky (about: 80% coarse sand and gravel, 20% cobbles). At the end of the basin, the soil surface is covered mainly by fine and coarse sand (Abd El-Wahab, 2003).

2.3. Wadi Sahab (Fig. 2) lies at about 40 km to the west of St. Catherine area, and 15 km of Feiran Oasis. It is a tributary of Wadi Feiran. Wadi Sahab is relatively flat and broad, on its bed there are no big boulders as those found in steep wadis. On the surface there are little stones. The soil may be considered to be sandy soil because sand constitutes the greatest part of soil at all depths (El-Naggar, 1991).

3. Climate

According to UNEP (1992), arid and semiarid environments occupy about 37% of the land on earth. Sixty four percent of the global dry lands and 97% of hyper arid desert are concentrated in Africa and Asia. South Sinai is characterized by an arid to extremely arid climate (Danin, 1986). Available meteorological data (rainfall, temperature, relative humidity, wind speed, and evaporation) of number of stations in South Sinai mainly collected from the Meteorological Authority, Water Research Centre, El-Tur Meteorological Station, and Saint Catherine Research Centre are summarized in Table (1).

Table 1. Available meteorological data of some stations in South Sinai, Egypt, compiled from different sources.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
St. Catherine 1979-1992 *												
Rainfall (mm)	5.9	1.9	6	0.5	0.4	0.0	0.0	0.1	0.0	0.7	0.9	2.7
Rel. Humidity (%)	49.8	43.3	39.4	28.6	24.9	27.2	28.8	30.1	28.1	31.9	34.2	42.7
M. Max. Temp. (°C)	14.3	15.1	17.7	24.4	28.3	30.8	31.8	28.7	27.7	26.1	20	16.3
M. Min. Temp. (°C)	1.4	1.4	4.6	9.0	12.5	16.3	17.5	16.2	13.6	11.5	6.8	4.3
Average Temp. (°C)	7.9	8.3	11.2	16.7	20.4	23.5	25	22.5	21	18.8	13.4	10.3
Evap. mm/day	5.7	7.2	9.3	12.6	15.2	17.7	16.2	13.7	11.7	10.4	7.2	6.1
El-Tur 1998-2002 **												
Wind speed (km/h)	11.2	12.1	12	14.6	14.5	17.2	14.6	15.8	15.3	12.4	9.8	9.8
Rel. Humidity (%)	42.7	46	48	51.8	62.9	66.5	67.4	67.1	65.6	65	57.7	47.1
M. Max. Temp. (°C)	19.4	21.2	24.3	26.9	29.7	30.6	33.3	33.4	31.8	28.8	25.5	22.6
M. Min. Temp. (°C)	11.5	12.8	15.4	18.5	22.1	23.9	26.2	26.9	26	22.3	15.5	12.5
Average Temp. (°C)	15.4	17	19.8	22.7	25.9	27.3	29.8	30.2	29	26	20.5	17.6

Evap. = evaporation, M. = mean, Max. = maximum, Min. = minimum, Rel. = relative,
Temp = temperature - * Abd El-Wahab (2003) ** El-Tur Meteorological Station

3.1 Temperature

Due to the wide range of altitude, South Sinai is characterized by a wide range of variation in air temperature. The lowest monthly mean minimum temperature ranges between 1.4°C at St. Catherine and 15.8°C at Sharm El-Sheikh, while the highest monthly mean maximum temperature varies between 30.8 and 35.8°C. St. Catherine is the coolest area in Sinai and Egypt as a whole due to its high elevation (1500-2641m asl). The low elevation wadis are warmer. Climatic data clarify the aridity situation of the study area and give an obvious note about climatic changes in St. Catherine and El-Tur areas.

3.2. Relative humidity and Evaporation

In St. Catherine area, the relative humidity (Table 1) ranges between 24.9% in May and 49.8% in January. The evaporation there is greater during summer than winter, with maximum of 17.7 mm in June and minimum of 5.7 mm in January.

3.3. Precipitation

Most of the precipitation in South Sinai occurs during winter and spring. Considerable precipitation occurs as a result of convective rains that are very local in extent and irregular in occurrence. Precipitation may occur as snow on the high peaks of South Sinai Mountains. The mean annual rainfall is 42.59 mm at Saint Catherine. The annual rainfall of Saint Catherine decreased from 60.4 mm in 1930's to 42.6 mm in 1990's (Abd El-Wahab, 2003). Rainfall in South Sinai is characterized by extreme variability in both time and space. The rainfall data in the historical past and recently revealed the occurrence of climatic cycles manifested by periods of rainy years alternating with droughty ones, with a general trend toward more aridity (Fig. 3). The spatial variability is extent in that one locality may have amount of rainfall that resulted in floods, and at the same time there is no rainfall in another locality a few kilometres

distant. Rainfall data recorded from two different stations at St. Catherine demonstrates this variability. The first station (1550m above sea level) recorded 72.6 and 119 mm for the years 1993 and 1994 respectively, while the other station (1350m above sea level) recorded 47.2, and 48.1 mm for those years respectively (Abd El-Wahab, 2003).

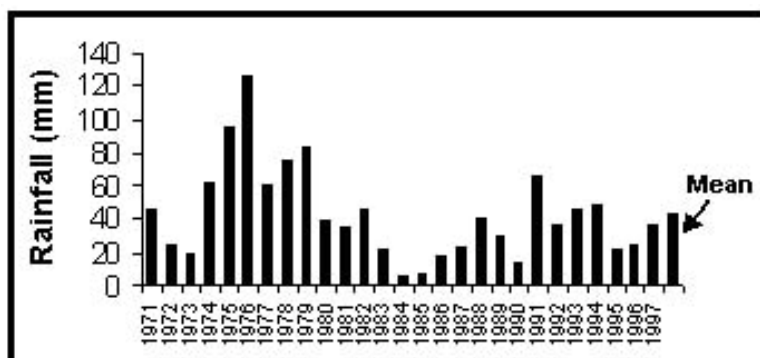


Fig. 3. Annual rainfall of St. Catherine (1971-1997).
Mean annual rainfall was 42.59 mm.

4. Vegetation and Flora

The Sinai Peninsula has the geographical importance of being the meeting place of Africa and Asia. Therefore, its flora combines elements from these two continents, Sahara-Arabian, Irano-Turanian, Mediterranean and Sudanian elements (McGinnies *et al.*, 1968; Zohary, 1973; and Moustafa, 1990). In general, the vegetation is characterized by sparseness of plant cover of semi shrubs, restricted to wadis or growing on slopes of rocky hills and in sand fields and paucity of trees (Danin, 1986). However the lower altitudes support vegetation only in wadis, while that of the upper altitudes have a diffuse pattern (Danin, 1978). The vegetation of St. Catherine area is characterized by the dominance of four families: Compositae, Labiatae, Leguminosae, and Cruciferae (Moustafa, 1990).

B. Western Mediterranean Coastal Desert (WMCD)

1. Location and Geography

The second study area was the Western Mediterranean Coastal Desert. Scorpions were collected from Bahig village near Burg El-Arab city which belongs to Alexandria Governorate (Fig. 1). It is bordered from the east by Alexandria city and from the west by El-Hammam city. The Mediterranean Sea coast represents the northern border of the study area. The WMCD is a distinct northern part of the Western Desert. This desert extends from Alexandria westward about 600 km to Sallum and varies in width from 15 to 30 km in the eastern and central sections to a few kilometres in the west, south of the cliffs at Sallum. Various names applied to this region such as Marmarica (Hassib, 1951), Mareotis District (Kassas, 1955), Western Mediterranean Coastal Region (Täckholm, 1956), and Qattara littoral (Meigs, 1966). This coastal desert differs from the Sinai littoral in the fact that it is calcareous rather than siliceous, it has a higher rainfall and relative humidity, low wind speed and temperature as well as it has the richest flora in Egypt other than that of the Gebel Elba area (Tadros, 1953 and MD-MD, 1994).

2. Geology and Geomorphology

At various intervals west of Alexandria, dunes of white oolitic sand form the coastline. Usually paralleling the sandy coast is a series of two valleys containing salt marshes alternating with limestone ridges (Shata, 1955). A few relatively short wadis

drain the annual runoff from the coastal desert. During heavy rains, they become torrents carrying large quantities of soil into the sea. With the introduction of irrigation water via canals from the Nile Delta, the coastal area as far west as El-Hammam is rapidly being changed. The most remarkable feature in the study area is the presence of a number of alternating ridges and depressions running parallel to the coast in the east-west direction. These ridges are formed from limestone with a hard crystallized crust and vary in altitude and lithological features according to the geological age (Ayyad, 1993)

3. Climate

3.1. Temperature and relative humidity

According to Tornwhite climatic classification methodology the WMCD region is classified as a semi-arid area. The annual mean temperature is 19.3°C and the annual mean relative humidity is 63.4%. Available meteorological data (rainfall, temperature, relative humidity, wind speed, and evaporation) of Alexandria Governorate, mainly collected from El-Dabaa Meteorological Station and Alexandria-Nouzha Meteorological Station, are summarized in Table (2).

3.2. Precipitation

The annual rainfall of Alexandria is 109 mm (Table 2). The WMCD from Sallum to the Nile Delta receives an average winter rainfall of 70-200 mm each year. The amount of rainfall decreases to about 80 mm at Port Said and to about half that of Alexandria at El-Arish in northern Sinai (Migahid *et al.*, 1955). A considerable amount of dew is precipitated on the WMCD during the rainless part of the year and is reported to be of significance to shallow rooted plants (Migahid & Ayyad, 1959).

Table 2: Available Meteorological data of Alexandria Governorate and WMCD, Egypt, compiled from different sources.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982-1994*												
Rainfall (mm)	127	72	57	1.1	12	2	0	16	12	58	168	159
Rel. Humidity (%)	62	60	58	60	59	67	69	71	65	65	68	57
M. Max. Temp. (°C)	18.1	18.9	20.3	22.7	25.5	27.8	29.2	19.9	28.7	27	22.4	19.7
M. Min. Temp. (°C)	8.1	8.4	9.7	11.8	14.5	18.2	20.2	21	19.7	16.8	13.3	10
Average Temp. (°C)	12.7	13.4	15	17.7	20	23.2	25	25.4	24.2	21.8	18.2	14.6
Wind Speed (km/h)	11.9	11.2	11.5	10.7	9.3	10	9.9	9	8.6	8.2	9.4	11.1
1998-2002**												
Wind speed (km/h)	6.8	7.9	8.6	8.1	8.5	9.7	9.3	9.1	7.9	7.5	6.6	7.1
Rel. Humidity (%)	65.7	61.4	61.1	61.5	69.5	75.5	75.7	75.8	71.9	69	68.6	56.2
M. Max. Temp. (°C)	17.5	21	21.9	24	25.8	27.6	30.5	31.7	30.6	31.8	24.4	20.5
M. Min. Temp. (°C)	9.1	9.4	10.9	13.8	17.5	21.5	23.5	24	22.1	18.4	14.4	10.6
Average Temp. (°C)	13.3	14.6	16.3	18.9	21.5	24.5	27.2	28	27	24	19.6	15.7

M. = mean, Max. = maximum, Min. = minimum, Rel. = relative, Temp = temperature

* El-Dabaa Meteorological Station (MD-MD, 1994) ** Alexandria-Nouzha Meteorological Station

3.3. Wind

The annual mean wind speed is about 12.6 km/hr (Table 2). Wind velocity is greater on the coast than inland; especially in winter (Migahid *et al.*, 1955) along with salt

spray, which is a major limiting factor suppressing development of vegetation on exposed ridges and cliffs near the seacoast.

4. Vegetation and Flora

The four phytogeographical zones of WMCD have been defined by Kassas (1955) as follows: (1) Littoral oolitic sand dunes, (2) Sublittoral and inland oolitic limestone ridges 3 km apart, (3) Salt marsh between the two rocky ridges, and (4) Inland plains. Grazing and cutting for fuel have completely removed the vegetation from extensive areas around towns and villages and affected it elsewhere. In areas developed to agriculture, native plants have been reduced to a few species (Boulos, 2002).

Material and Methods

The present work has been designed to investigate the intraspecific diversity of the morphological characters of *Scorpio maurus palmatus* (Ehrenberg, 1828) in Egypt. This scorpion species was chosen for the following reasons: (1) it is distributed in both arid and semiarid habitats, (2) it lives alone and not in communities inside burrows along its life cycle, and (3) the unique structure of its venom as well as its pharmacological properties. The scorpions were collected from two different geographical locations in Egypt. The first was the southern region of Sinai Peninsula, which represents the arid area and the second area that represents the semiarid area, was the western Mediterranean coastal desert (WMCD).

Samples collecting: Scorpions were collected from the study areas, i.e. WMCD, Wadi Sahab, Wadi El-Agramia and Wadi Rahaba, during August-September, 2001. They were collected during daytime by observing, surveying and locating the location of their burrows followed by excavation of the inhabitants (Williams, 1968a). The captive scorpions were kept alive in separate suitable plastic containers, in order to avoid cannibalism. At the same time, the depths of the scorpion's burrows were measured and their different shapes and designs were also drawn. The scorpion specimens' species from all sites were identified according to the key of El-Hennawy (1987). Random soil samples were taken from all sites for physical and chemical analysis. In addition, the available plants and insects around the scorpion's burrows were collected and identified in Faculty of Science, Suez Canal University, Ismailia, Egypt.

Preservation of scorpion samples: For taxonomic and morphological studies, scorpions were treated according to Williams (1968b), as follows:

1. Killing: Heat shock is accomplished by dropping living specimens into hot water (90-99°C) until the metasoma straightens out.
2. Fixation: Immediately after killing, specimens were rinsed and left for 12-48 hours in the following fixative: a. Formalin, commercial strength: 12 parts, b. Isopropyl alcohol 99%: 30 parts, c. Glacial acetic acid: 2 parts, d. Distilled water: 56 parts.
3. Permanent storage: Specimens were rinsed in 50% isopropyl alcohol for an hour and transferred to 70% isopropyl alcohol for permanent storage in a dark place to avoid fading.

Morphometric measurements of scorpions

Ten adult individuals of each sex were collected from each location (WMCD, Wadi Sahab, Wadi El-Agramia. and Wadi Rahaba) for morphological analysis. Maturity was determined by body size and secondary sexual characteristics. In males, the length of the genital papillae was the primary indicator of maturity; sexually mature males

manifested a pronounced papilla compared with immature (Polis & Farley, 1979). For females, the smallest gravid individual offspring in each population was used as a crude measure of maturity; all larger females were considered mature.

We analyzed 10 meristic (countable) and 29 continuous characters. The following meristic characters were measured: number of pectinal teeth (right and left), denticles of the sixth row on the fixed pedipalp finger (right and left), sixth row denticles of the movable pedipalp finger (right and left), number of setae on the first and second right legs, and the third leg (right and left). The continuous measured characters were: total body length, carapace length, pedipalp length (from base to the tip of the fixed finger), pedipalp hand (length and width), fourth right leg femur length, mesosoma length, metasoma length, metasomal segments from 1-5 (length, width and height), telson (length and width), pectinal teeth length (right and left), and marginal lamellae length of pecten (right and left). Scorpion mensuration was standardized by Stahnke (1970), and the continuous measurements were taken with a vernier calliper of 0.05 mm accuracy and eye piece micrometer (1/100 mm graduation). All measurements are in millimetres.

Analysis of the environmental factors: In an attempt to reveal a relationship between environmental factors and diversity of scorpions morphology, the following measurements were taken. Surface soil samples (0-30cm depth) were collected from the four locations in tightly plastic containers (5 replicas from each site) and transferred to the laboratory. Soil samples were air-dried, thoroughly mixed and sieved through a 2 mm sieve to exclude large particles that are less reactive (Robertson *et al.*, 1999).

Physical analysis of soil

1. Grain size analysis: The air-dried samples were disaggregated by hand and then split using a cone and quarter technique. About 50 grams of the prepared samples were taken for mechanical analysis using standard sets of sieves. All samples were shaken in Ro-Shaker for 15 minutes. The collected sieve fractions were accurately weighed and grain-size parameters were statistically calculated (Folk, 1974).

2. Total moisture content: The actual moisture content of the soil fluctuates depending upon the composition of the soil, topographic location, and climatic variation. A soil sample is weighed in a tarred aluminium container, placed in an oven, and dried at 105°C. Then the sample is reweighed, and the content of moisture is expressed as percentage of the oven dry weight (Wilde *et al.*, 1972).

Chemical analysis of soil

1. Soil pH is a measure of hydrogen ion activity in the soil solution. Soil pH is probably the single most informative measurement that can be made to determine soil characteristics. It can be used to make a rough estimate of availability of some essential nutrients (Thomas, 1996). Soil pH was measured electrometrically, using pH meter model HI 8014 Hanna Ins. Italy, in soil suspension of ratio 1 : 5 soil to water. The soil-water mixture was first shaken for 2 hours then pH was measured (Jackson, 1974).

2. Electrical Conductivity and Total Dissolved Salts

Electrical conductivity (EC) is a numerical expression of the ability of an aqueous solution to carry an electric current. It is generally related to the total solute concentration and can be used as a quantitative expression of dissolved salt concentration (Rhoades, 1996). Soil EC was measured in soil water extract 1 : 5 using conductivity meter model HI 8033 Hanna Ins. Estimation of total dissolved salts (TDS) in (mg/L) was calculated by multiplying values of EC obtained by 640 (Westerman, 1990).

3. Soil Organic Matter (SOM)

Soil organic matter influences many soil properties, including (i) the capacity of soil to supply nitrogen, phosphorus, and trace metals to plants, (ii) infiltration and retention of water, (iii) degree of aggregation and overall structure that affect air and water relationships, (iv) cation exchange capacity, (v) soil colour. SOM was measured using loss-ignition method carried out at high temperature. This method gives quantitative oxidation of organic matter (Nelson & Sommers, 1996).

Data Analysis

Data were statistically analyzed using SPSS software (Statistical Package for Social Science, Version 11.01) (Dancey and Reidy, 2002). Tabulation and graphics of data were done using Microsoft Excel XP. Descriptive statistics analyses including mean, standard error (Zar, 1984) were applied to all the morphometric measurements of scorpions and environmental factors in each locality to have a preliminary description about the status of the morphological characters of the scorpions from the different locations.

1. Variation within population

To explain variation within each population of scorpions (sexual dimorphism), comparison between all the morphological characters of males and females in each location was done. Student's unpaired *t*-test was used to reveal this hypothesis.

2. Variation among populations

One-way ANOVA was carried out to test this hypothesis for all morphological characters (variables) of scorpions. ANOVA was applied to find out if there is a significant difference between males from different sites (site is a covariate) and between females from separate sites as well. In addition, One-way ANOVA was used to test variation in the environmental factors between different sites. Duncan's multiple range post ANOVA test, was carried out to determine which means differ within different areas for those variables showing significant *F* ratio. Two-way factorial ANOVA design using General Linear Model (GLM) was used to examine the effect of site as a covariant and sex as the other covariant in the diversity of scorpion's morphology.

3. Association between morphological characters and environmental factors

Linear correlation coefficient (*r*) also called Pearson product moment correlation coefficient was applied to find out the relationship between morphometric measurements (meristic and continuous) of scorpions and environmental factors.

4. Canonical Discriminant Functions Analysis (DFA)

Discriminant Functions Analysis (DFA), a multivariate technique, allows input of several variables to investigate the morphometric relationship among several populations. It maximizes among-group distances while shrinking within-group dispersion to resolve patterns among groups (Albrecht, 1980 and Reymont *et al.*, 1984).

5. Similarities in the morphometric measurements between scorpion populations

Hierarchical cluster analysis was carried out to measure the similarity distance in the morphometric measurements among scorpion populations.

Results

Habitat Characteristics

Nature of soil

Results in Table (3) illustrate physical and chemical properties of soil samples collected from the study areas (WMCD, Wadi Sahab, Wadi El-Agramia and Wadi Rahaba). Statistical analysis of various soil parameters revealed high significant difference between localities. Soil physical properties: moisture, cobble sand, pebble sand and very fine sand showed high values of *F* ratio with high significance between different localities. The same results were observed in the soil chemical properties; total dissolved salts and electrical conductivity (Table 3).

Generally, soil of the study areas Wadi Sahab, Wadi El-Agramia and Wadi Rahaba were light or yellowish brown in colour, sandy, characterized by low content of silt and clay, alkaline (pH 7.4-8.1), non-saline to slightly saline (EC 0.08-0.11), low content of soil organic matter (SOM 0.4-0.66%) and low content of soil moisture (Moisture 0.47-0.53%). On the other hand, soil from WMCD was yellowish brown or dark brown and it has high contents of soil organic matter, soil moisture, total dissolved salts, silt and clay when compared with those from South Sinai.

Scorpions' burrows

Burrows of *S. m. palmatus* have different structures (Fig. 4). Maximum scorpion burrow depth was recorded in Wadi Sahab (88±6.6 cm) while the minimum depth was recorded in WMCD (12±1.2). There was a significant difference in the depth of scorpions burrows between sites ($P < 0.01$) (Table 3).

Table 3: Descriptive and statistical analysis of chemical and physical properties of soil samples from the different study locations.

Variables (n = 5)		WMCD	South Sinai			ANOVA $F_{1,3}$
			Sahab	El-Agramia	Rahaba	
Soil pH		6.9 ± 0.032 ^a	7.4 ± 0.2	8.1 ± 0.06	8.1 ± 0.04	21*
Total dissolved salts (mg/l)		4.6 ± 0.19	0.06 ± 0.01	0.08 ± 0.01	0.05 ± 0.03	520*
Electrical conductivity (u-mohs)		7 ± 0.01	0.09 ± 0.05	0.11 ± 0.02	0.08 ± 0.06	660*
Total organic matter (%)		1.2 ± 0.019	0.4 ± 0.03	0.66 ± 0.01	0.53 ± 0.02	30.1*
Soil Moisture (%)		4.4 ± 0.7	0.47 ± 0.07	0.5 ± 0.07	0.53 ± 0.02	194*
Soil Texture						
Sand (%)	Cobble (%)	12.3 ± 0.18	8.5 ± 0.18	14.1 ± 0.23	4.2 ± 0.13	480*
	Pebble (%)	6.8 ± 0.85	24.4 ± 0.16	22.4 ± 0.24	13 ± 0.07	333*
	Very coarse (%)	8.2 ± 0.5	27.4 ± 0.22	21.5 ± 1.4	20.1 ± 0.15	99.2*
	Coarse (%)	14.6 ± 0.8	19.6 ± 0.25	11.5 ± 0.31	22.8 ± 0.14	105*
	Medium sand (%)	17.1 ± 1.02	11.1 ± 0.15	10.5 ± 0.28	18.1 ± 0.13	37.3*
	Fine sand (%)	22.1 ± 2.4	4.8 ± 0.1	8.1 ± 0.38	10.6 ± 0.14	37.4*
	Very fine sand (%)	11.3 ± 0.18	1.34 ± 0.06	4.6 ± 0.19	4.7 ± 0.09	810*
Silt (%)		3.7 ± 0.8	0.78 ± 0.04	2.2 ± 0.2	1.9 ± 0.06	7.2*
Clay (%)		2.6 ± 0.6	1.2 ± 0.14	6.1 ± 0.11	4.3 ± 0.39	24.8*
Burrow depth (cm / n=20)		12.0 ± 1.2	88.0 ± 6.6	35.0 ± 5.4	26.0 ± 3.6	49.5*

* = *F* ratio is significant at $P < 0.01$ a = Mean ± Standard error

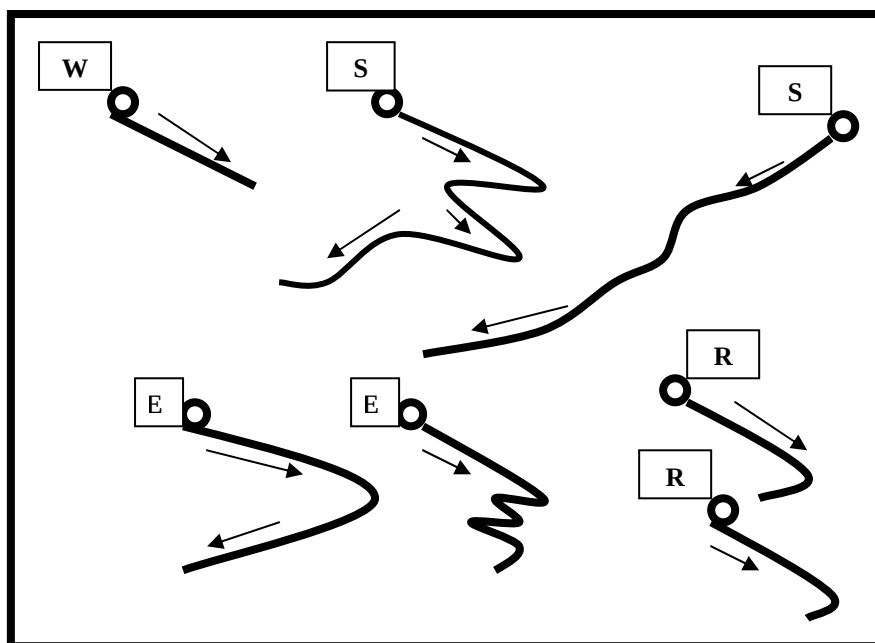


Fig. 4. Variation in the burrow shapes of the scorpion *Scorpio maurus palmatus*. Circles represent burrow entrances. W = WMCD, E = El-Agramia, R = Rahaba, S = Sahab.

Collected insects and plants: Available insects and plants around the scorpions' burrows were collected. Variation in insects populations and plants species among study areas was also found. The identified insects from the WMCD were *Eleodes* sp. and *Phytomiger* sp. (Order Coleoptera), whereas *Adesmia* sp., (Order Coleoptera) was collected from the other locations (Wadi Sahab, Wadi El-Agramia and Wadi Rahaba). Collected plants from WMCD were *Atriplex* sp. and *Mesembryanthemum* sp. while *Ochradenus baccatus* and *Anabasis articulata* were gathered from Wadi Sahab. *A. articulata* was collected from Wadi El-Agramia, and *Zilla spinosa*, *A. articulata* and *Fagonia mollis* were collected from Wadi Rahaba.

Morphological analysis of the scorpion *S. m. palmatus*

Colouration: Generally, colouration of *S. m. palmatus* showed different grades of the yellow colour, where the body was light olive to yellow, legs lighter, fingers and fifth segment of metasoma with telson partially darker, and legs with a dark spot at base of femur. Colour of scorpions that were collected from South Sinai area was slightly different from that collected from WMCD. The fingers and fifth segment of metasoma in WMCD population was lighter than that of South Sinai populations.

Morphometric measurements

Variation within population

Scorpion morphometric measurements (continuous and meristic) are summarized in Tables (4, 5). At first, there was a difference in the sex ratio relative abundance between males and females in all locations (Table 4). It was noticed that in El-Agramia, most of the morphometric measurements revealed significant differences between males and females. These variables are total body length, carapace length, mesosoma length, pedipalp length, pedipalp hand length, 4th leg femur length, 2nd metasomal segment length and width, 3rd metasomal segment length, telson length, number of right and left pectinal teeth, number of 1st, 2nd and 3rd right leg setae. On the other hand, number of pectinal teeth (right and left) showed a significant difference between males and females in all study areas (Table 5).

Table 4: Descriptive and statistical analysis of the continuous morphometric measurements of the scorpion *S. m. palmatus* collected from different studied locations.

Character		WMCD		South Sinai					
				W. Sahab		W. El-Agramia		W. Rahaba	
		♂	♀	♂	♀	♂	♀	♂	♀
Sex ratio		1	2.5	1	3.6	1	2.8	1	3.1
Total body L		52.7 ^a ± 1.2	52.5 ± 1.8	48 ± 1.8	50 ± 1.1	39.7 ± 0.76	43.1* ± 0.6	42.3 ± 1.1	43 ± 1.2
Carapace L		8.1 ± 0.2	8.2 ± 0.2	7.4 ± 0.2	7.7 ± 0.1	6.1 ± 0.1	6.6* ± 0.11	6.4 ± 0.14	6.7 ± 0.2
Pedipalp L		28.1 ± 0.5	28.9 ± 0.7	24 ± 1	26 ± 0.6	20.1 ± 0.5	22.2* ± 0.7	22.4 ± 0.3	23.4 ± 0.5
Pedipalp hand	L	13.6 ± 0.32	14.4 ± 0.4	12 ± 0.7	12 ± 0.25	8.9 ± 0.27	10.4* ± 0.36	10.9 ± 0.30	11.7 ± 0.33
	W	7.5 ± 0.22	7.6 ± 0.28	5.9 ± 0.33	6.2 ± 0.21	4.7 ± 0.21	5.2 ± 0.11	5.3 ± 0.21	5.0 ± 0.15
4 th Leg femur L		7 ± 0.2	7.2 ± 0.31	7.3 ± 0.25	7.5 ± 0.16	6.1 ± 0.2	6.7* ± 0.19	6.4 ± 0.13	6.7 ± 0.10
Mesosoma L		16.3 ± 0.42	17.3 ± 0.7	15 ± 0.5	16 ± 0.5	12.1 ± 0.5	13.9* ± 0.3	13.6 ± 0.6	14.4 ± 0.6
Metasoma L		28.2 ± 0.7	27 ± 0.7	25 ± 1.1	26 ± 0.5	21.3 ± 0.62	22.4 ± 0.3	22.3 ± 0.34	21.8 ± 0.6
1 st metasomal segment	L	3.2 ± 0.1	3.1 ± 0.08	2.8 ± 0.2	2.7 ± 0.1	2.4 ± 0.08	2.4 ± 0.06	2.5 ± 0.07	2.3* ± 0.06
	W	4.2 ± 0.12	4.1 ± 0.1	3.3 ± 0.15	3.3 ± 0.08	2.8 ± 0.06	3.0 ± 0.13	3.0 ± 0.06	2.7* ± 0.12
	H	2.9 ± 0.06	2.9 ± 0.09	2.3 ± 0.07	2.5* ± 0.06	2.1 ± 0.04	2.1 ± 0.05	2.2 ± 0.10	2.1 ± 0.09
2 nd metasomal segment	L	3.6 ± 0.13	3.4 ± 0.12	3.1 ± 0.16	3.1 ± 0.09	2.6 ± 0.1	2.8* ± 0.06	2.7 ± 0.09	2.7 ± 0.14
	W	3.9 ± 0.10	3.8 ± 0.12	3.1 ± 0.15	3 ± 0.04	2.5 ± 0.05	2.8* ± 0.07	2.6 ± 0.06	2.3 ± 0.1
	H	2.8 ± 0.05	2.7 ± 0.1	2.1 ± 0.08	2.3 ± 0.07	1.9 ± 0.07	1.9 ± 0.07	2.1 ± 0.12	2.01 ± 0.10
3 rd metasomal segment	L	4.0 ± 0.11	3.8 ± 0.09	3.6 ± 0.14	3.6 ± 0.08	2.9 ± 0.1	3.1* ± 0.05	3.1 ± 0.06	3.0 ± 0.11
	W	3.6 ± 0.1	3.5 ± 0.1	2.7 ± 0.14	2.8 ± 0.08	2.3 ± 0.07	2.5 ± 0.07	2.3 ± 0.07	2.4 ± 0.12
	H	2.6 ± 0.06	2.5 ± 0.06	2.2 ± 0.11	2.2 ± 0.01	1.8 ± 0.09	1.8 ± 0.05	2.0 ± 0.1	1.8 ± 0.06
4 th metasomal segment	L	4.7 ^a ± 0.14	4.6 ± 0.11	4.4 ± 0.19	4.4 ± 0.11	3.6 ± 0.09	3.7 ± 0.07	3.7 ± 0.05	3.7 ± 0.12
	W	3.2 ± 0.1	3.1 ± 0.10	2.5 ± 0.11	2.5 ± 0.07	2.2 ± 0.08	2.2 ± 0.11	2.2 ± 0.06	2.0 ± 0.06
	H	2.4 ± 0.05	2.3 ± 0.05	2.0 ± 0.11	1.9 ± 0.03	1.6 ± 0.04	1.7 ± 0.04	1.9 ± 0.08	1.7 ± 0.11
5 th metasomal segment	L	6.2 ± 0.2	5.8* ± 0.24	5.8 ± 0.25	6.0 ± 0.12	5.1 ± 0.15	5.2 ± 0.12	5.2 ± 0.09	5.2 ± 0.17
	W	2.4 ± 0.07	2.2 ± 0.08	1.9 ± 0.08	2.1 ± 0.04	1.7 ± 0.06	1.8 ± 0.06	1.8 ± 0.06	1.7 ± 0.07
	H	2.0 ± 0.04	1.9 ± 0.08	1.5 ± 0.09	1.7 ± 0.04	1.4 ± 0.04	1.5 ± 0.03	1.6 ± 0.06	1.4 ± 0.03
Telson	L	6.3 ± 0.14	6.1 ± 0.16	5.4 ± 0.28	5.9 ± 0.13	4.7 ± 0.16	5.0* ± 0.06	4.8 ± 0.08	4.7 ± 0.2
	W	2.5 ± 0.09	2.3 ± 0.11	2.0 ± 0.1	2.0 ± 0.09	1.8 ± 0.06	1.8 ± 0.06	1.7 ± 0.09	1.9 ± 0.06
Marginal Lamellae L of Pecten	R	4.7 ± 0.16	4.4 ± 0.14	3.9 ± 0.17	3.7 ± 0.13	3.3 ± 0.12	3.4 ± 0.06	3.6 ± 0.08	3.4 ± 0.09
	F	4.8 ± 0.13	4.3 ± 0.16	3.8 ± 0.16	3.7 ± 0.13	3.3 ± 0.09	3.4 ± 0.06	3.6 ± 0.09	3.4 ± 0.08
Pectinal teeth length	R	0.75 ± 0.02	0.6 ± 0.03	0.6 ± 0.02	0.6 ± 0.03	0.57 ± 0.03	0.54 ± 0.02	0.59 ± 0.01	0.52 ± 0.03
	F	0.7 ± 0.02	0.65 ± 0.01	0.6 ± 0.02	0.5 ± 0.01	0.56 ± 0.02	0.51 ± 0.02	0.59 ± 0.01	0.5 ± 0.02

a = Mean ± SE (n=10), * = Significant difference using Student's unpaired *t*-test (*p*<0.05),
L = length, W = width, H = height, R= Right, F = left.

Variation among populations

Tables 6 and 7 summarize the continuous and meristic morphometric measurements of the scorpion *S. m. palmatus* collected from different locations. One-way ANOVA for males from all locations revealed highly significant difference in all continuous characters and some meristic characters. The meristic characters that did not reveal significant difference were the number of denticles of 6th row on fixed and movable fingers of right and left pedipalps. The same result was obtained for females but the meristic characters that did not show significant differences were the number of denticles of 6th row on only left fixed and movable fingers of pedipalp.

Table 5: Descriptive and statistical analysis of the meristic (countable) characters of the scorpion *S. m. palmatus* collected from the four different studied locations.

Character		WMCD		South Sinai					
				Sahab		El-Agramia		Rahaba	
		♂	♀	♂	♀	♂	♀	♂	♀
No. of pectinal teeth	R	10.9 ^a ± 0.23	10* ± 0.14	10 ± 0.33	9.8 ± 0.29	10.3 ± 0.15	9.3* ± 0.3	9.8 ± 0.2	8.9* ± 0.23
	F	10.7 ± 0.42	10.1 ± 0.27	10.4 ± 0.16	9.7* ± 0.21	10.2 ± 0.2	9.3* ± 0.33	10 ± 0.14	8.8* ± 0.24
No. of Setae on leg	1 st R	16.7 ± 0.47	15.7 ± 0.36	16.7 ± 0.47	17.2 ± 0.44	16.7 ± 0.47	15* ± 0.47	18.4 ± 0.45	18.3 ± 0.21
	2 nd R	18.3 ± 0.42	18.5 ± 0.40	18.6 ± 0.56	19.3 ± 0.63	17.6 ± 0.26	16.7* ± 0.44	20.1 ± 0.37	20.2 ± 0.46
	3 rd R	19.9 ± 0.37	18.8 ± 0.57	21.9 ± 0.51	21.5 ± 0.47	17.8 ± 0.44	19.4* ± 0.63	21.5 ± 0.52	21.9 ± 0.37
	3 rd F	20.2 ± 0.53	19 ± 0.51	22.7 ± 0.33	22.2 ± 0.44	18.9 ± 0.43	19.5 ± 0.58	21.6 ± 0.70	22.5 ± 0.5
No. of denticles of 6 th row on pedipalp's fingers									
fixed	R	7.0 ± 0.29	6.7 ± 0.21	7.3 ± 0.26	8.4* ± 0.4	7.6 ± 0.45	7.8 ± 0.44	8.1 ± 0.54	8.1 ± 0.34
	F	7.3 ± 0.36	6.7 ± 0.26	7.7 ± 0.39	8.3 ± 0.49	7.5 ± 0.42	7.9 ± 0.5	8.3 ± 0.3	7.9 ± 0.37
movable	R	3.6 ± 0.22	3.3 ± 0.15	3.3 ± 0.15	4.0 ± 0.21	3.0 ± 0	3.3 ± 0.15	3.4 ± 0.16	3.6 ± 0.16
	F	3.5 ± 0.16	3.3 ± 0.21	3.2 ± 0.13	3.4 ± 0.22	3.3 ± 0.15	3.1 ± 0.17	3.3 ± 0.15	3.6 ± 0.16

a = Mean ± SE (n=10), * = Significant difference using Student's unpaired t-test (p<0.05) R = right, F = left

Table 6: The statistical output of the continuous morphometric measurements of the scorpion *S. m. palmatus* collected from the four different studied locations.

Character			Males from all locations	Females from all locations
			ANOVA F _{1,3}	ANOVA F _{1,3}
Total body L			19.7**	15.1**
Carapace L			24.8**	17.2**
Pedipalp L			23.7**	19.7**
Pedipalp hand		L	19.6**	22.8**
		W	26.3**	35.2**
4 th Leg femur L			7.2**	3.50*
Metasomal segment	1 st	L	13.5**	18.8**
		W	33.5**	29.8**
		H	24.6**	22.6**
	2 nd	L	12.8**	10.2**
		W	38.2**	43.3**
		H	19.6**	10.0**
	3 rd	L	18.4**	20.3**
		W	30.5**	24.3**
		H	12.7**	38.4**
	4 th	L	14.9**	14.7**
		W	28.5**	26.9**
		H	16.9**	18.0**
	5 th	L	7.9**	5.80*
		W	17.3**	13.8**
		H	16.6**	15.2**
Telson		L	17.7**	19.4**
		W	13.4**	5.50*
Marginal Lamellae L of Pecten		R	17.2**	15.1**
		F	24.9**	14.1**
Pectinal teeth length		R	11.9**	4.01**
		F	11.7**	8.1**

* = F ratio is significant at P<0.05, ** = F ratio is significant at P<0.01, L = length, W = width, H = height.

Table 7: The statistical output of the meristic (countable) characters of the scorpion *S. m. palmatus* collected from the four different studied locations.

Character		Males from all locations	Females from all locations
		ANOVA F _{1,3}	ANOVA F _{1,3}
No. of pectinal teeth	R	4.01*	3.9*
	F	1.30	4.16*
No. of Setae on leg	1 st R	3.50*	14.7*
	2 nd R	6.2*	8.4*
	3 rd R	6.2**	8.4**
	3 rd F	15.6**	12.4**
No. of denticles of 6 th row on pedipalp's fingers	fixed finger	R	4.2*
		F	2.7
	movable finger	R	3.7*
		F	1.13

* = *F* ratio is significant at the 0.05 level. ** = *F* ratio is significant at $P < 0.01$ level. R = right, F = left.

Variables showing significant *F* ratio were supported with Duncan's multiply range test to determine which means differ within different areas. Means that do not differ from one another are displayed in separate column or subset. In males (Table 8), total body length, pedipalp length, and number of 3rd left and right legs setae revealed a remarkable significant difference between locations ($P < 0.01$). While in females, pedipalp length and pedipalp hand length (Table 9B) showed this remarkable significant difference ($P < 0.01$).

Table 8 (A, B): Output of Duncan's multiply range test, showing variation in the morphometric measurements between males of *S. m. palmatus* collected from the four different studied locations. Means for groups in homogeneous subsets are displayed.

(A)		Total Body Length (mm)			Pedipalp Length (mm)			
	N	Subset for alpha = .05						
		1	2	3	1	2	3	4
El-Agramia	10	39.7700			20.1800			
Rahaba	10	42.3100				22.4300		
Sahab	10		47.9900				24.6200	
WMCD	10			52.7300				28.1600
Sig.		0.179	1.000	1.000	1.000	1.000	1.000	1.000

(B)		No. of the 3 rd left leg setae			No. of the 3 rd right leg setae		
	N	Subset for alpha = .05					
		1	2	3	1	2	3
El-Agramia	10	18.9000			17.8000		
WMCD	10	20.2000	20.2000			19.9000	
Rahaba	10		21.6000	21.6000			21.5000
Sahab	10			22.7000			21.9000
Sig.		0.085	0.065	0.143	1.000	1.000	0.552

The two-way factorial ANOVA model (Site + Sex) for the scorpion morphometric measurements (Table 10) revealed a highly significant site effect ($P < 0.01$) in all morphological characters and significant sex effect in the following characters: right and left pectinal teeth length, 4th leg femur length, pedipalp hand length, pedipalp length, mesosoma length and carapace length ($P < 0.05$). The interaction between sex and site revealed a highly significant difference for all morphological characters of *S. m. palmatus* scorpions ($P < 0.01$).

Table 9 (A, B): Output of Duncan's multiply range test, showing variation in the morphometric measurements between females of *S. m. palmatus* collected from the four different studied locations. Means for groups in homogeneous subsets are displayed.

(A)	N	Total Body Length(mm)	
		Subset for alpha = .05	
		1	2
Rahaba	10	43.0300	
Agramia	10	43.1200	
Sahab	10		49.9800
WMCD	10		52.5500
Sig.		0.959	0.152

(B)		Pedipalp Length (mm)			Pedipalp hand Length (mm)			
	N	Subset for alpha = .05						
		1	2	3	1	2	3	4
El-Agramia	10	22.2200			10.4400			
Rahaba	10	23.4000				11.7300		
Sahab	10		26.5400				12.9900	
WMCD	10			28.9800				14.4100
Sig.		1.00	1.00	1.00	1.000	1.000	1.000	1.000

Table 10: The statistical output (2-Way Factorial ANOVA) of the interaction between sex and location of some morphometric measurements of the scorpion *S. m. palmatus* collected from different studied locations using General Linear Model (GLM).

Character		Sex	Location	Interaction
		ANOVA (F ratio)	ANOVA (F ratio)	ANOVA (F ratio)
Total body L		2.2	72.0**	793**
Carapace L		5.9*	88.2**	865**
Pedipalp L		6.1*	67.**	609**
Pedipalp hand	L	5.2*	45.1**	358**
	W	0.72	112**	507**
4 th Leg femur L		3.8*	13.7**	519**
Mesosoma L		7.1*	32.5**	369.1**
Metasoma L		0.03	77.4**	848**
1 st metasomal segment	L	1.1	70.3**	631**
	W	0.24	119**	644**
	H	0.43	80.6**	572**
2 nd metasomal segment	L	0.02	55.5**	483**
	W	0.02	159**	725**
	H	0.49	52.7**	451**
3 rd metasomal segment	L	0.14	82**	822**
	W	0.74	111**	541**
	H	2.4	78**	606**
4 th metasomal segment	L	0.17	69.2**	811**
	W	1.4	123**	656**
	H	0.85	51**	449**
5 th metasomal segment	L	0.07	27.8**	604**
	W	1.7	64**	593**
	H	0.01	45.3**	454**
Telson	L	0.55	87**	721**
	W	0.62	38**	347**
Marginal Lamellae L o Pecten	R	1.7	51**	564**
	F	2.6	60**	635**
Pectinal teeth length	R	8.2*	31.4**	477**
	F	10.7*	39.9**	557**

* = F ratio is significant at the 0.05 level, ** = F ratio is significant at the 0.01 level.
L = length, W = width, H = height, R = right, F = left.

Relationships between morphological characters and environmental factors

As a first step, we conducted a multiple correlation analysis (Pearson product moment correlation), entering all morphometric measurements of scorpions (continuous and meristic) and all environmental variables (altitude, soil physical properties, soil chemical properties and scorpion burrow depth). Because of the very large number of tests carried out, only the most significant of these are presented in Table (11).

Pearson correlation matrix of some morphometric measurements and environmental factors indicated the obvious interaction between them. Total body size and pedipalp length showed a significant negative correlation with a number of environmental factors such as altitude ($r = -0.67$, -0.67), soil pH ($r = -0.73$, -0.73), pebbles sand ($r = -0.33$, -0.4), very coarse sand ($r = -0.32$, -0.4), clay ($r = -0.62$, -0.6) and scorpion burrow depth ($r = -0.24$, -0.36). At the same time, they showed highly significant positive correlation with soil total dissolved salts ($r = 0.58$, 0.64), soil electrical conductivity ($r = 0.59$, 0.64), soil moisture ($r = 0.51$, 0.54) and total organic matter ($r = 0.47$, 0.52) respectively.

Significant negative correlation was also recognized between number of right and left pectinal teeth and altitude ($r = -0.41$, -0.40), soil pH ($r = -0.28$, -0.28) respectively. Number of 1st, 2nd, and 3rd right legs setae and number of 3rd left leg setae were also significantly correlated with altitude ($r = 0.35$, 0.20 , 0.26 , 0.28), cobble sand ($r = -0.52$, -0.63 , -0.56 , -0.5), coarse sand ($r = 0.55$, 0.58 , 0.63 , 0.62) and very fine sand ($r = -0.32$, -0.29 , -0.54 , -0.59) respectively.

Table 11: Correlation between environmental factors and some morphometric measurements of the scorpion *S. m. palmatus* collected from different locations using Pearson Correlation.

Environmental factor	TBL	PEDL	NRP	NLP	N1RLS	N2RLS	N3RLS	N3LLS
Altitude (m)	-0.67**	-0.67**	-0.41**	-0.40**	0.35**	0.20*	0.26*	0.28**
pH	-0.73**	-0.73**	-0.28*	-0.28*	0.15	-0.01	0.02	-0.02
Total dissolved salts	0.58**	0.64**	0.37**	0.31**	-0.20*	-0.08	-0.27*	-0.33*
Electrical conductivity (u-mohs)	0.59**	0.64**	0.35*	0.29*	-0.20*	-0.08	-0.27**	-0.33**
Total organic matter (%)	0.47**	0.52**	0.31*	0.30*	-0.27**	-0.19	-0.39**	-0.41**
Moisture (%)	0.51**	0.54**	0.33*	0.30*	-0.17	-0.09	-0.26*	-0.28**
Cobble (%)	0.08	0.02	0.28*	0.22*	-0.50**	-0.60**	-0.56**	-0.50**
Pepple (%)	-0.33**	-0.40**	-0.15	-0.10	-0.07	-0.17	0.10	0.18
Very coarse (%)	-0.32**	-0.40**	-0.25*	-0.17	0.17	0.10	0.37**	0.44**
Coarse (%)	-0.04	0.01	-0.25*	-0.17	0.55**	0.58**	0.63**	0.62**
Medium sand (%)	0.31**	0.44**	0.09	0.06	0.20	0.30**	0.05	-0.03
Fine sand (%)	0.41**	0.50**	0.26*	0.19	-0.12	-0.01	-0.27*	-0.35*
Very fine sand (%)	0.15	0.20	0.24*	0.15	-0.32**	-0.29**	-0.54**	-0.59**
Silt (%)	0.18	0.27*	0.19	0.10	-0.13	-0.09	0.38**	-0.45**
Clay (%)	-0.62**	-0.60**	-0.18	-0.22*	-0.08	-0.24*	-0.36**	-0.36**
Burrow depth (cm)	-0.24*	-0.36**	-0.10	-0.05	-0.12	-0.20	0.07	0.16

* Correlation is significant at $P < 0.05$ (2-tailed), ** at $P < 0.01$ (2-tailed). TBL = total body length, PEDL = pedipalp length, NRP = number of right pectinal teeth, NLP = number of left pectinal teeth, N1RLS, N2RLS, N3RLS = number of 1st, 2nd, and 3rd right leg setae, N3LLS = number of 3rd left leg setae

Canonical Discriminant Functions Analysis

A. Males: Canonical Discriminant Functions Analysis (DFA) was used to detect variation in the morphometric measurements among sites. For males (Fig. 5), the four sites were very distinct along the first and the second axes. Along the first axis, WMCD has positive

values and Wadi El-Agramia, Wadi Rahaba have negative values with Wadi Sahab being in between. Positive values along this axis were correlated most with total body length, carapace length, pedipalp length, telson width, number of right pectinal teeth, and negative values being associated with mesosoma length, metasoma length and 4th leg femur length. Along the second axis, Wadi Rahaba has positive values and Wadi El-Agramia has negative ones, while WMCD and Wadi Sahab are in between. Positive values along this axis were associated with carapace length, mesosoma length, metasoma length, pedipalp length, number of 2nd right leg setae with negative values of total body length, 4th leg femur length and number of right pectinal teeth.

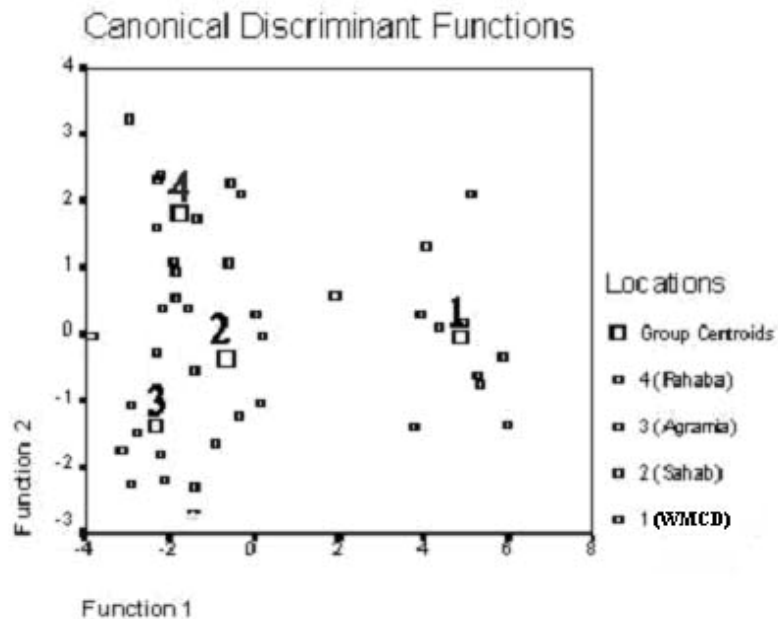


Fig. 5. Canonical Discriminant Functions Analysis (DFA) of *S. m. palmatus* males.

B. Females: The female DFA plot (Fig.6) was slightly congruent to the male plot. Also, the four sites were very distinct along the first and the second axes in females plot. Along the first axis, WMCD has a positive value against negative ones for Wadi Sahab and Wadi Rahaba, with Wadi El-Agramia being in between. Positive values along this axis were mainly correlated to carapace length, mesosoma length, metasoma length, pedipalp length, pedipalp hand length, marginal lamellae length of right pecten, right pectinal teeth length, 1st and 2nd metasomal segment length and width. Negative values being associated with total body length, pedipalp hand length, marginal lamellae length of left pecten, left pectinal teeth length, and 5th metasomal segment height.

Along the second axis, Wadi El-Agramia has a positive value while WMCD and Wadi Sahab have negative values. Positive values correlated with carapace length are: mesosoma length, pedipalp length, 5th metasomal length, 1st metasomal segment length, 2nd metasomal segment length, width and height. Negative values are associated with total body length, metasoma length, pedipalp hand length and width, 1st metasomal segment width and height, and 3rd metasomal segment length and height. Data plotted in Figs. 5, 6 and 7 (Hierarchical Cluster Analysis) revealed the following: 1- a significant discrimination between the four sites, 2- WMCD and Wadi Sahab were congruent to each other, 3- Wadi El-Agramia and Wadi Rahaba are also similar to each other, and 4- within population, males were similar to females.

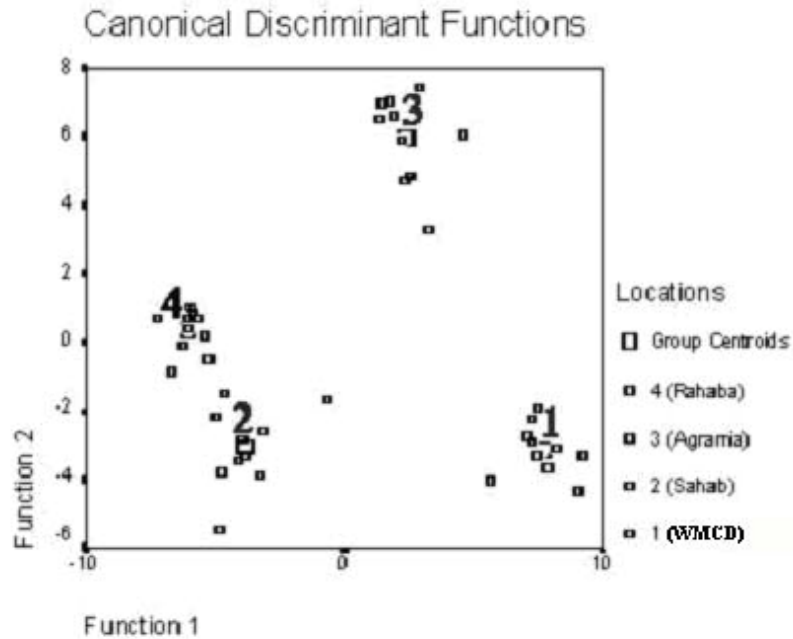


Fig. 6. Canonical Discriminant Functions Analysis (DFA) of *S. m. palmatus* females.

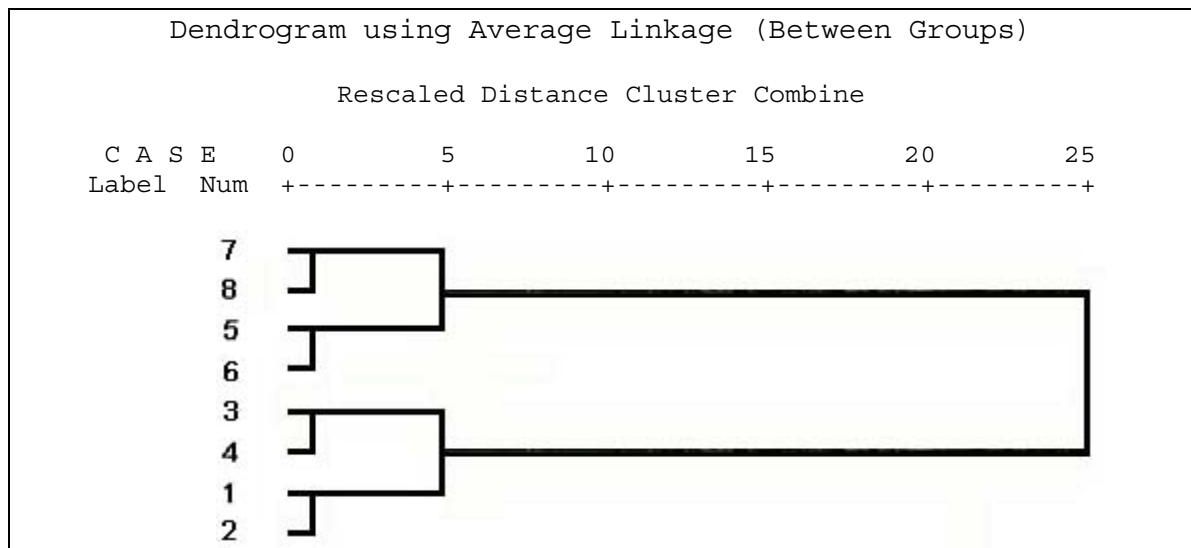


Fig. 7. Hierarchical Cluster Analysis.

1 = Males, 2 = Females of WMCD; 3 = Males, 4 = Females of W. Sahab;
5 = Males, 6 = Females of W. El-Agramia; 7 = Males, 8 = females of W. Rahaba.

Discussion

Although numerous scorpion species are found in Egypt, intraspecific variation and diversity in the Egyptian scorpions has never been studied before. In the current study, not only intraspecific variation in scorpion's morphology was examined but also environmental and ecological factors that may contribute influence and/or cause this variation. Because *Scorpio maurus palmatus* is distributed in two different habitats, arid and semiarid, in Egypt and even it exists in dense population in some areas it lives

solitarily in burrows at high altitude and at the sea level, it was taken as a model to study intraspecific variation.

As members of populations, individual organisms are part of communities that over time evolve to suit the environment which they inhabit, providing that these stay constant long enough for adaptation to occur. An individual species can live only within a certain tolerance of environmental factors; the effect of too much or too little of any factor may inhibit growth or even prove fatal (Leeming, 2004). Many physical factors influence the spatial distribution of scorpions, including temperature, precipitation, soil or rock characteristics, stone or litter cover and environmental physiognomy (Polis & McCormick, 1986).

In the present study, coordinates of the study areas and data in Tables 1, 2 and 3 revealed three main important points; 1) the four different localities studied, i.e. WMCD, Wadi Sahab, Wadi El-Agramia and Wadi Rahaba, are spatially isolated, 2) each locality has its different habitat features and 3) the scorpion *S. m. palmatus* is adapted to survive in these different environments. Leeming (2004) reported that animal species are adapted to conditions in their local environments. Many animal species adapt to gradual geographic changes in climate. Such adaptation is often expressed in the phenotype as a measurable change in size, colour, or other traits.

Scorpions are almost associated with deserts. The extreme physical and climatic conditions of the desert environments have engendered in them a number of interrelated morphological, behavioural and physiological adaptations (Hadley, 1972). Burrowing is a major adaptation of many scorpion species for survival in extreme environments. Differences in micro-habitat influence burrow depth and morphology. Koch (1977) found that the burrows of many species of Australian scorpions varied in relation to average rainfall. Burrows are deeper and more spiralled in arid central areas than in wetter coastal areas. Burrow depth for *Opisthophthalmus* scorpions in southern Africa varied with soil type (Eastwood, 1978). Hardness and physical characteristics of the soil are important for many species (Polis & McCormick, 1986). In this study, significant variation in both climatic factors (temperature, relative humidity and rainfall) and nature of soils (soil hardness and texture, soil organic matter and soil moisture) could be the main reasons in the highly significant difference of scorpions burrows depths and shapes among locations. The maximum depth and very complicated structure of burrows were recorded in Wadi Sahab (Table 3, Fig. 4). This may be due to the soil of Wadi Sahab is characterized by the high content of sand and low content of silt, clay, and organic matter as well as the low level of soil moisture when compared with the other areas. Scorpions such as *Opisthophthalmus* sp. and *Scorpio maurus* protect themselves from desiccation in different ways. They shelter in burrows, where temperature and humidity of the burrow can be regulated, the deeper the burrow the cooler the ambient temperature inside the burrow (Leeming, 2004).

Among the studied specimens of *S. m. palmatus*, there are intraspecific colour variants among populations manifested in the degree of darkness in fingers and fifth metasomal segment of South Sinai populations which is more obvious and characteristic than scorpions of WMCD area. This variation may be attributed to the adaptation of the animal species to gradual geographic changes in climate. Such adaptation is often expressed in the phenotype as a measurable change in size, colour, or other trait. This finding is in agreement with Leeming (2004).

Sexual dimorphism in scorpions was reviewed by Kraepelin (1907), Koch (1977), Farzanpay & Vachon (1979) and Ali *et al.* (2001). Secondary sexual characteristics may be placed in the following categories (modified by Koch, 1977): 1) differences in body size, 2) differences in the shape of body structures, 3) the presence of a feature in one sex

but not in the other, 4) stronger development of features in one sex than in the other, 5) differences in the texture of the body surface, and 6) higher meristic in one sex than in the other. In general, females are larger than males (Koch, 1977). Sexual dimorphism in body size appears to be extremely common among scorpions, although in many taxa the differences are not significant. The shape of structures may often be variable between the sexes. Dimorphism is commonly expressed by elongation of the pedipalp and/or metasoma in males (Polis & Sisson, 1990). Finally, the sexes may differ in meristic characters, such as pectinal tooth counts. Males tend to have more pectinal teeth than females. Behavioural and ecological differences also exist between males and females (Polis, 1990). Data in Tables (4 and 5) reveal significant differences in most of the morphometric measurements (length of: total body, carapace, mesosoma, pedipalp, 4th leg femur, 2nd and 3rd metasomal segments, telson and number of: right and left pectinal teeth, 1st, 2nd and 3rd right legs' setae) between males and females in El-Agramia Plain. This variation could be attributed to the sexual dimorphism phenomena in scorpions. The question here is: why only in El-Agramia ? The main reasons that might in the answer are: 1) El-Agramia Plain is one of the most important physiographic features of St. Catherine area (Shendi, 1992) and 2) the characteristic local diversity manifested in the habitat heterogeneity of this wadi system (Semida *et al.*, 2001 and Abd El-Meniem *et al.*, 2003). Local diversity is generated and maintained by a complex of factors, such as altitude, latitude, productivity, climatic variability, age of ecosystem, predation, competition, spatial heterogeneity or the stage of the biological succession (Fjeldsa & Lovett, 1997). Local diversity is then a complex function of regional diversity and faunistic turnover among localities (Caley & Schuller, 1997).

Variation between males and females were not only found in the morphometric measurements but also exist in the sex ratio relative abundance (Table 4). Difference in sex ratio relative abundance could be attributed to the mortality rate of males, which may be higher than females. This difference produces the heavily skewed sex ratio ($\sigma : \phi = 1: 2.5, 1: 3.6, 1: 2.8, 1: 3.1$) observed for scorpions that were collected from WMCD, Wadi Sahab, Wadi El-Agramia and Wadi Rahaba respectively. Differential mortality is attributed to several behavioural differences between males and females. Mature males are often vagrant and mobile during mating season. This characteristic high activity predisposes them to a disproportionately higher incidence of cannibalism, predation by other scorpion species or by vertebrate and invertebrate predators, starvation, and thermal death. This mobility also makes it likely that mature males feed less and construct more temporary burrow than females or young males. These findings were observed by Polis & Sisson (1990) and Ali *et al.* (2001).

Species vary in morphological and genetic patterns across their geographical ranges. These patterns can provide insight into how factors such as natural selection and population subdivision can mould populations. Investigations of morphological variation among geographic races have provided insights into mechanisms of character divergence and speciation (Myers, 2001). In this work, we focused on possible factors responsible for, and the ecological implications of, the dramatic variation in adult body size, pedipalp length, number of pectinal teeth and number of leg setae in the desert scorpion *S. m. palmatus*.

Body size is a fundamental trait affecting virtually every aspect of an organism's biology. Size influences the metabolic and structural characteristics of individuals and their ability to accommodate cold, heat, water, and other environmental stresses (Colder, 1984). Size also influences ecological interactions by affecting an individual's status as potential competitor, predator, or prey (Ebenman & Persson, 1988). Most species do not contain adults of uniform size. Researchers study size differences to gain ecological and

evolutionary insights, but discovering the cause of variance, even within a single species, is confounded by the many environmental and selection factors acting now and in the past to shape this character (Myers, 2001).

This is the first study of the intraspecific variation in the adult body size and its relative measurements of *Scorpio maurus palmatus* in Egypt. Total body length in both males and females revealed high significant differences between the four locations (Table 6). Duncan's multiply range test supports this result (Table 8 and 9). The largest scorpions (males and females) are found in WMCD population (30m above sea level) while the smallest are females of Wadi Rahaba population (1676m above sea level) and males of Wadi El-Agramia population (1225m above sea level). Difference in body size among populations could be attributed to difference in the size of available prey; large ones are more efficiently handled by large predators (Case & Cody, 1983). It is important to mention that the size of the captive preys (beetles) which were collected from WMCD is larger than the preys of St. Catherine area. Consequently, this factor indicated that why scorpions of WMCD population recorded the highest adult body size in both males and females. Myers (2001) found that high feeding rates and prey availability are the most consistent environmental factors associated with large size in scorpions.

Distance and altitude are other important environmental factors in the variation of scorpion's body size. The significant negative correlation between total body length and altitude (Table 10) accords with McCormick & Polis (1986) who found a 20% difference in body size among adult *Paruroctonus mesaensis* separated by only 15 km.

Finally, the significant difference between scorpions of WMCD population and South Sinai populations total body length may be due to the difference in climatic factors (especially: precipitation, humidity, wind speed and temperature) between these regions. Scorpions in Wadi El-Agramia and Wadi Rahaba may suffer from sub-optimal growth conditions due to the prolonged cold season compared to conditions in Wadi Sahab and WMCD. Also, strong winds in St. Catherine (South Sinai) area cause dryness the upper soil layer, destroy seedlings, shorten leaf and flowering periods by increasing transportation, and suppress animal activity. These observations coincide with those of Warburg & Elias (1998). Warburg *et al.* (1980) reported that *Scorpio maurus* is by far the most characteristic species of the Mediterranean region. This species prefers areas of high precipitation, dense vegetation and deep soil. Apparently these factors also provide them with a suitable microclimate for maintaining optimal water and thermal balance.

Interestingly the sense organs (leg sensory hairs or leg setae) of specimens revealed high significant differences among our populations. The large number in the sensory hairs of scorpions at high altitudes (positive significant correlation coefficient, Table 10) may be due to special adaptation of these animals. Sensory hairs large numbers in scorpions increase their ability to receive low frequency waves in warm dry air, which has poor wave-carrying qualities, or vibrations in densely packed sand. Brownell & Farley (1979) found that the tarsal sensory hairs are stimulated by substrate vibrations along with the slit sensilla. These setae respond best to compressional waves, and the receptors consist of a single bundle of cell bodies below each hair socket, which give rise to dendritic processes terminating on a cuticular fold at the base of each shaft. Our observations explaining sensory adaptations in scorpions were in agreement with Fet *et al.* (1998).

Canonical Discriminant Functions Analysis (DFA) and Hierarchical Cluster Analysis (HCA) plots (Figs. 5-7) show that populations close in geographical distance exhibit similar coordinate in the DFA and HCA graphs. In the males, three populations (Wadi Sahab, Wadi El-Agramia and Wadi Rahaba) cluster, indicating that overall morphological distances are not very large. On the other hand, WMCD population is

highly distinct from the other populations in St. Catherine area. These results indicate that morphological differentiation among populations may result from local environmental conditions (Dillon, 1984).

In the females plots, interestingly even within St. Catherine area, a distinct morphological distance between population of Wadi Sahab and Wadi El-Agramia was found. At the same time, El-Agramia is closely related to population of Wadi Rahaba than the other locations. In the population of sand scorpion, *P. mesaensis*, the morphological analysis showed a geographical association among regional sites. A positive association was found among genetic, morphological and geographical distance matrices. However, the morphological distance matrix showed a higher correlation value with geographical distance than genetic distance. The local environmental conditions may affect scorpion morphology more than genetic structure among populations (Yamashita & Polis, 1995).

Accordingly, it can be concluded that: 1) *Scorpio maurus palmatus* exhibits a general morphological separation between populations, 2) intraspecific diversity in this species may be due to variation in the environmental conditions (biotic and abiotic factors), 3) site and sex as covariates (using General Linear Model Analysis) play an essential role in the intraspecific variation of scorpion's morphology and 4) total body length, pedipalp length and number of setae on legs can be used as good markers to examine intraspecific diversity of most scorpion species.

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***Oecobius amboseli* Shear & Benoit, 1974, a new record from Egypt (Araneida : Oecobiidae)**

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Abstract

Oecobius amboseli Shear & Benoit, 1974 (Family Oecobiidae) is recorded from Cairo, Egypt. The male of this species is described for the first time.

Keywords: Male description, Spiders, Oecobiidae, *Oecobius amboseli*, Egypt.

Introduction

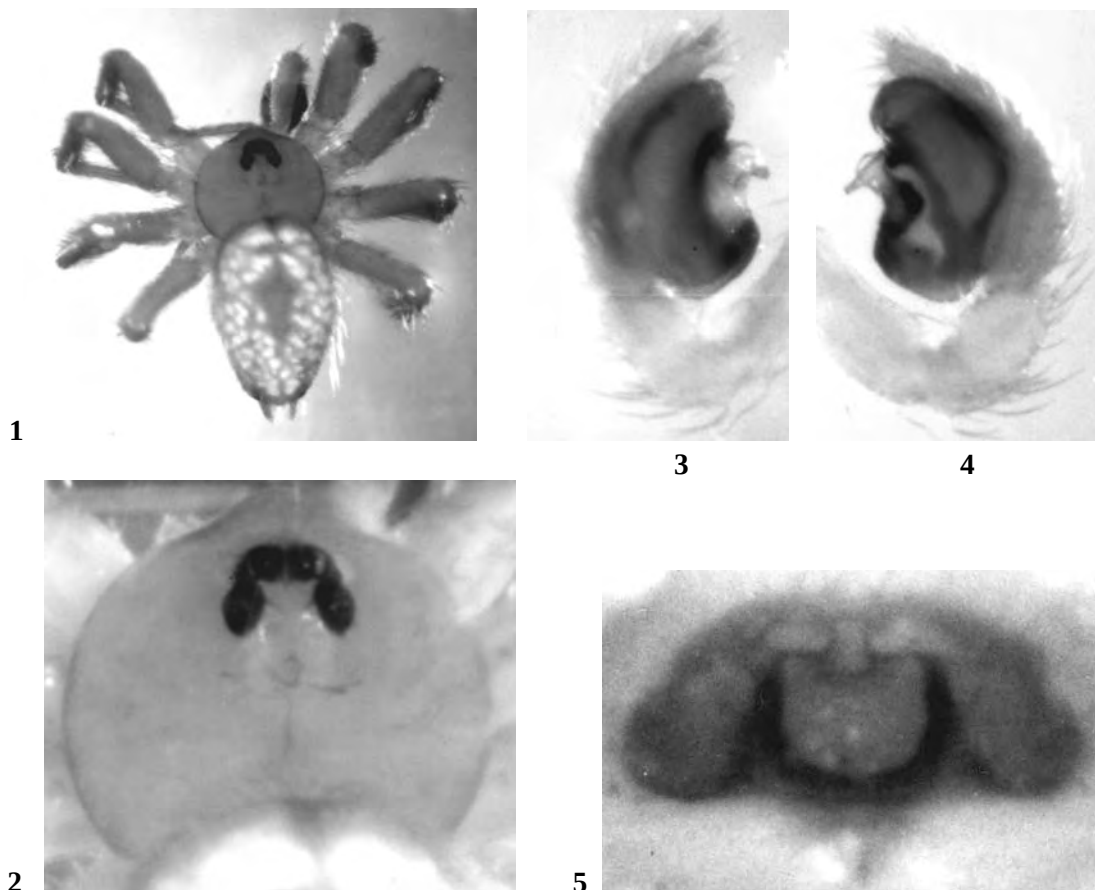
There are 78 species and one subspecies of genus *Oecobius* Lucas, 1846 recorded from our world (Platnick, 2004). Only four species of them were recorded from Egypt (El-Hennawy, 2002), i.e. *O. maculatus* Simon, 1870, *O. navus* Blackwall, 1859, *O. putus* O.P.-Cambridge, 1876, and *O. templi* O.P.-Cambridge, 1876. Hassan (1953) described all these species, partly under synonymous names. The discovery of other *Oecobius* species is expected in Egypt.

In 1990, I found a male and a female of an *Oecobius* species, which is different from the Egyptian species. The female's epigynum is very similar to that of the Kenyan *O. amboseli* Shear & Benoit, 1974; a species, which has only a unique female holotype (MRAC no. 141741) from Massai Amboseli Reserve, Kenya, collected by P.L.G. Benoit, 8 September 1972, and the male is wanting. The Massai Amboseli Reserve is located at the foot of Mt. Kilimanjaro, on the border of Kenya with Tanzania. After few years, Dr. David Penney collected one male and two females of *O. amboseli* from Uganda. Through comparing the Egyptian specimens with the Ugandan material, it becomes possible to confirm the identification and to describe the male of this species for the first time.

Abbreviations used: ALE = anterior lateral eye; PLE = posterior lateral eye; PME = posterior median eye.

Material from the following collections were examined: ACE = Arachnid Collection of Egypt, Cairo, Egypt; MRAC = Musée Royal de l'Afrique Centrale, Tervuren, Belgium.

All measurements are in mm.



Figs. 1-5: *Oecobius amboseli* Shear & Benoit, 1974. 1, 2. Male. 1. Habitus; 2. Carapace, dorsal view. 3, 4. Male palp. 3. Prolateral view; 4. Retrolateral view. 5. Female epigynum, ventral view.

***Oecobius amboseli* Shear & Benoit, 1974**
(Figs. 1-11)

Material examined

I. Egypt: One male was collected from the building of the Criminal Investigation Laboratory, Bab El-Khalq, Cairo, Egypt [30°02'44"N 31°15'09"E Alt. 39m] on 1st January 1990 (ACE 19900101.1), and two females were collected from the same building on 7th January 1990 (ACE 19900107.1) and 8th May 1999 (ACE 19990508.1). All of them were found walking on the wall. [Note: *O. templi* is dominant in this locality.]

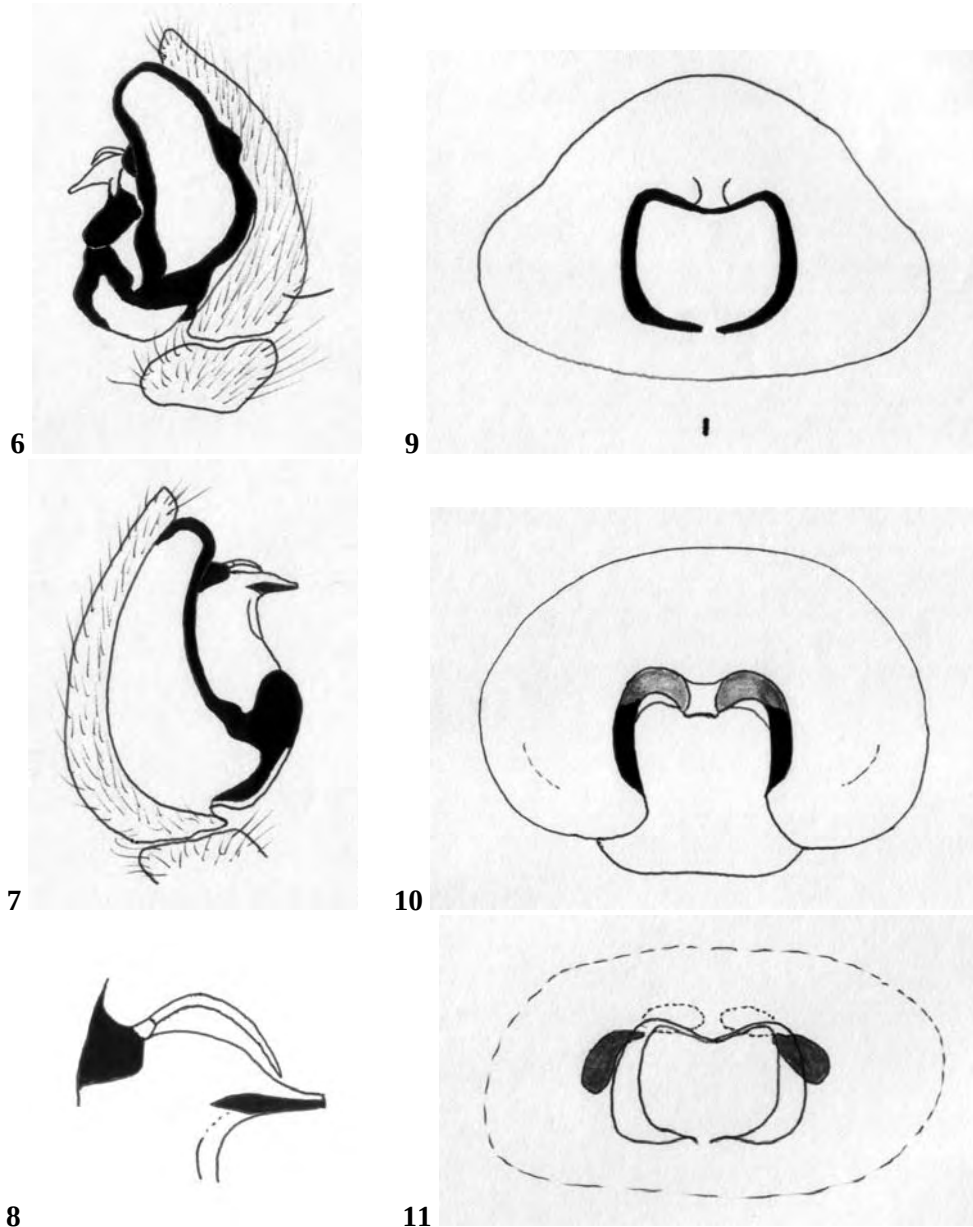
A female was collected from the building of Faculty of Science, Ain Shams University, Cairo, Egypt [30°04'46"N 31°17'07"E Alt. 46m] on 28th June 1987 (ACE 19870628.1), and a male from the same building on 16th April 1991 (ACE 19910416.1). They were collected from their nests. [Note: *O. putus* is dominant in this locality and *O. templi* is found too.]

The five specimens were collected by the author and deposited in the Arachnid Collection of Egypt (ACE) in Cairo, Egypt.

II. Uganda: One male and two females of: *Oecobius amboseli*; Det. Penney D. 1995; Loc. Uganda, Rubaga, Kampala, outside walls of building; Rec. Penney D., VII. 1994; Mus.R.Afr.Centr. 215071.

Diagnosis

Oecobius amboseli can be distinguished from the other known *Oecobius* species by genitalic characters: the finely pointed median apophysis and its position with the embolus of the male palpal organ (Figs. 6-8), and the very simple epigynum distinguished by a large central fossa and widely separated vulvae of the female (Figs. 9-11).



Figs. 6-11: *Oecobius amboseli* Shear & Benoit, 1974. 6-8. Male palp. 6. Retrolateral view; 7, 8. Prolateral view (8. detail). 9-11. Female. 9. Epigynum, ventral view; 10. Epigynum, proventral view; 11. Vulvae, dorsal view.

Description

The Egyptian specimens are in concordance with the characters of genus *Oecobius* (Shear, 1970, p.135) and the description of the holotype of *Oecobius amboseli* (Shear & Benoit 1974, pp. 717, 719).

Male (ACE 19900101.1). Total length: 1.87. Carapace (Fig. 2) yellowish-brown with blackish border and blackish tinctures in front and behind eyes with a distinctly projecting sub-triangular clypeus; a few setae are present in the ocular area and behind it; 0.68 long, and 0.87 wide. Eyes: anterior row almost straight, posterior row procurved, ALE and PME light, PLE largest, ALE smallest, PME irregularly subtriangular, separated by their diameter. Sternum heart-shaped, with wide base separating between the coxae of the fourth legs. Legs yellowish-brown, lighter than carapace, densely covered by hairs, leg I: Femur 0.85, Patella 0.31, Tibia 0.65, Metatarsus 0.61, Tarsus 0.44, Total length 2.86. Length of Patella-Tibia I : Width of carapace 1.103. Abdomen (Fig. 1) spindle-shaped with white irregular patches among light brown ones densely covered by long hairs, 1.22 long, and 0.82 wide. Palpal organ (Figs. 3, 4, 6, 7) characterized by its finely pointed median apophysis and its position with the embolus of the male (Fig. 8).

Colour variation: ♂ (ACE 19910416.1): carapace and legs yellowish-white.

Female (ACE 19900107.1). As male, except for the following: Total length 2.27. Carapace with three black patches on each side attached to the blackish border and a broad blackish area behind eyes extending to the posterior edge of the carapace in a narrower shape, 0.78 long, 0.92 wide. Leg I: Femur 0.88, Patella 0.32, Tibia 0.66, Metatarsus 0.65, Tarsus 0.48, Total length 2.99. Length of Patella-Tibia I : Width of carapace, 1.065. Abdomen with a few dark brown patches, 1.53 long, 1.19 wide. Epigynum is very simple, distinguished by a large central fossa (Figs. 5, 9, 10) and widely separated vulvae (Fig. 11).

Colour variation: ♀ (ACE 19870628.1): carapace and legs yellow, without black patches.

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